larger storm of September 29, 1915. Compared to the average gradient in the 50 miles between Bay St. Louis and New Orleans, in the 1915 storm 0.02 inch per mile, the average gradient between New Orleans and Houma, a distance of 48 miles, in the storm of August, 1926, was 0.023 inch per mile. On August 25, 1926, at 9.30 p. m., there was a difference of 0.66 inch between the barometer readings at Morgan City and Houma, 30 miles apart. As the storm center was slightly west of Houma, we have here a difference of at least 0.66 inch in a distance of less than 30 miles.

After passing Houma the storm decreased in intensity but retained considerable energy until it passed into St. Landry and Evangeline Parishes, where it damaged only crops. Heavy rainfall ceased with the passage of the storm center.

The previous report referred to the lack of high tides west of the center. At some points on the Louisiana coast, notably in the vicinity of Morgan City, the northeast gales on the storm front produced an unusually low tide; the lowest reading of the river gauge at Morgan City was 2.5 feet below zero at 6.45 p. m. of the 25th, about 6 feet below mean low tide. This is very remarkable, for the lowest previous river gauge reading at Morgan City was 0.2 foot above zero.

The Atchafalaya River connects with Grand Lake, a considerable body of water immediately northwest of Morgan City, and with the Gulf to the south, of which the nearest coast line is at right angles to a northeast offshore wind. This wind, blowing with hurricane force, lowered the water along the coast, particularly on the north side of Atchafalaya Bay, where the river empties into the Gulf, and may also have checked the rate of flow from Grand Lake into the river. When the wind backed to northwest, between midnight and 1 a. m. of the 26th, the water in the Gulf, relieved of the unusual strain, began to return to the north and east sides of Atchafalaya Bay, increasing the height of water in the river. A small peninsula, Point au Fer, extends westward from the Terrebonne coast and with westerly gales favors some accumulation of water at the mouth of the Atchafalaya. Simultaneously the northwest gale on Grand Lake increased the flow from that source. The resulting rise of 7.3 feet brought the river back to slightly more than the usual stage in about six hours.

Radiophone broadcasting and reception made possible a better distribution of warnings than in previous storms. In view of the intensity of the hurricane, the large number of people engaged in fishing and other coast industries, and the very slight elevation of the swampy areas in southern Terrebonne Parish, where the storm was most violent, the loss of life, 25 persons, is considered small. Reports of property loss and damage due to the storm are not all in; but trustworthy information indicates that property damage of all kinds, exclusive of crops in the field, was between $3,000,000 and $4,000,000 and that damage to crops will reach an equal or somewhat higher figure.

PERSISTENCE OF WEATHER TYPES IN THE HAWAIIAN ISLANDS

551.515 (969)

By E. F. Loveridge

[Weather Bureau Office, Honolulu, T. H.]

An inspection of a chart showing mean annual temperatures for a series of years in temperate latitudes does not disclose any tendency to a progressive warming or cooling. On the other hand, in the Tropics this tendency has been frequently noted, particularly by Henry (1) and Braak (2) for Batavia, Java. In tropical regions the variability of temperature and pressure is very slight, hence any systematic influence affecting these elements, such as sunspots or volcanic acivity, would be much more noticeable in these regions than in temperate latitudes, where variability is great and of accidental or fortuitous nature.

Clough (3) has shown by various statistical methods that the sequence of temperature changes from year to year do not follow the laws of chance variations.

In the United States there is a certain amount of persistence of temperature departures from month to month and year to year which is most strongly pronounced in central and southern California. Rainfall and atmospheric pressure do not show as much tendency to persist, but where large areas are taken into consideration there is some tendency of rainfall to persist from month to month during the summer season, at least in some sections.

In order to obtain an idea as to just what tendency there is for one month to be followed by a month of the same temperature sign in the United States, this was computed for 10 representative stations. The percentage of cases ranged from 65 at San Diego to 54 at Salt Lake City. Over eastern United States the result was quite uniform with an average of about 56 per cent, and the tendency toward persistence was greatest during late summer and the least during middle spring, the extreme monthly range averaging 10 per cent.

The persistence tendency probably varies somewhat with the length of record, and with a period of a hundred years or more it can be clearly shown that there is a relation between one month and the same month of the year in the succeeding years. This has been done with the St. Paul, Minn., record covering a period of 105 years, and the result is shown in Table 1. An inspection of this table offers very little encouragement to one who is looking for the effects of periodicities. For example, in the 11-year sunspot period if it were very strong there would be a well-marked positive correlation between months 11 years apart, and a negative correlation between months of about half this period. There is, however, a slight positive correlation shown in the table between months 11 or 12 years apart which is the most noticeable for the winter months.

TABLE 1.—*Percentage of times in which one month has the same temperature sign as the same month of the year during each of the following years up to 16, for St. Paul, Minn.*

Month	First year	Second year	Third year	Fourth year	Fifth year	Sixth year	Seventh year	Eighth year	Ninth year	Tenth year	Eleventh year	Twelfth year	Thirteenth year	Fourteenth year	Fifteenth year	Sixteenth year
January	51	48	56	50	44	48	58	47	55	55	52	49	59	42	39	44
February	55	50	49	43	47	51	43	53	52	56	59	60	51	49	47	43
March	62	57	57	56	51	46	56	53	59	58	57	54	59	51	42	52
April	53	55	45	46	55	51	59	45	59	47	49	58	51	56	53	52
May	63	49	49	43	52	48	50	53	49	49	47	39	38	46	52	55
June	64	58	47	44	51	47	49	53	51	60	57	58	60	57	59	55
July	59	61	43	56	49	54	54	45	49	43	52	51	53	41	40	49
August	60	52	57	62	61	51	54	51	42	40	40	51	42	36	47	50
September	59	45	50	57	49	46	51	54	43	40	53	59	56	40	51	51
October	50	60	49	52	47	51	46	55	51	53	49	56	51	46	49	53
November	64	59	54	52	55	49	51	48	52	49	50	51	50	48	47	54
December	54	44	47	50	57	48	50	58	41	47	51	47	49	48	52	57
Means	58	53	50	51	52	49	52	51	50	50	51	53	52	47	48	51
Winter means	53	47	51	51	49	49	50	53	49	53	54	52	53	46	46	48
Summer means	61	57	49	54	54	51	52	50	47	48	50	53	52	45	49	51

The most evident relation brought out is the percentage of times in which the month of one year has the same temperatures sign as the same month of the following year. This averages 58 per cent for all months and 61 per cent for the summer months. It would be interesting to determine the effect of length of record on these percentages. Probably they would be less with shorter records as in long records there are well-known long-period oscillations.

At Honolulu, a complete record of temperature goes back to the year 1890, and a record of atmospheric pressure to 1891 with the year 1904 missing. Cox (4) has worked out a 10-station average of Hawaiian rainfall beginning with the year 1877 and ending 1921. I have extended this record so as to bring it up to the end of 1925 for the annual amounts and 1924 for the monthly amounts.

It is apparent that these records are too short to show progressive changes unless such changes are well-marked and the variations slight. With Hawaiian temperatures such is the case and the progressive changes are clearly evident; but as rainfall shows a much greater variability, progressive changes, except for a period of a few months which will be shown later, are not in evidence. The same is true of atmospheric pressure and wind velocity.

Applying the ratio $\frac{u}{v}$ to Honolulu temperature in which u is the mean variability, and v the mean deviation, the result is 1.12. The corresponding value is 1.48 for Honolulu pressure and 1.52 for Hawaiian rainfall. The theoretical ratio is 1.414. No progressive change from year to year is shown by this test, therefore, except for temperature.

In Table 2 is shown the percentage of cases in which each month of the year has the same temperature sign as each of the succeeding months up to six, and also of the succeeding twelfth month, for both Honolulu and Tokio, Japan. Being situated on the eastern side of a great continent the climate of Tokio is largely continental, and is comparable with the climate of eastern United States at about the latitude of Virginia as regards both storminess and extremes of temperature.

TABLE 2.—*Percentage of cases in which each month of the year has the same temperature sign as each of the succeeding months up to six, and the succeeding twelfth month, for Honolulu, Hawaii, and Tokio*

Month	Honolulu							Tokio						
	First	Second	Third	Fourth	Fifth	Sixth	Twelfth	First	Second	Third	Fourth	Fifth	Sixth	Twelfth
January	56	52	55	61	52	59	47	48	44	33	55	73	41	38
February	63	69	69	53	56	55	50	50	72	45	60	59	55	53
March	76	73	55	48	57	46	50	58	39	53	39	50	64	50
April	77	68	61	61	58	53	53	30	55	58	43	48	30	34
May	71	64	69	61	59	38	57	42	34	65	44	55	59	33
June	70	75	74	71	38	57	53	50	53	56	55	58	52	38
July	76	76	72	34	70	63	62	66	48	53	52	37	52	47
August	72	71	53	62	65	69	66	69	55	70	55	53	50	52
September	87	61	64	55	71	67	50	69	71	57	48	52	56	66
October	62	79	69	73	59	53	59	60	62	47	41	58	62	40
November	53	37	73	60	57	59	62	71	62	65	60	50	48	37
December	74	72	72	61	67	53	64	66	59	50	50	55	52	59
Means	70	66	66	58	59	56	56	56	54	54	50	54	52	46

The table brings out the difference in persistence between the two places, Honolulu representing a marine tropical climate, and Tokio a continental temperate climate though these two climates are not represented

to their fullest degree. For purposes of comparison the period of record used was the same for both places; namely, 1890 to 1924, inclusive. It was thought that if different lengths of record were taken the results might be seriously altered.

As will be observed from the table, a month has the same sign as the preceding month in 70 per cent of the cases. For Hawaiian rainfall (Cox's 10-station average) the corresponding average is 66 per cent; for Honolulu pressure, 65; and for Honolulu wind velocity with a record of only 20 years, 57 per cent.

Using Clough's fifth criterion in the article previously referred to it can be shown that in Hawaii long periods in which a meteorological element, especially temperature, is persistently above or below the normal are much higher than in a random series of events. Beginning with the month of June, 1908, there were 21 consecutive months in which the Honolulu temperature was below normal. There were two cases in which the temperature was above or below the normal for 13 consecutive months, and one case each of 11, 12, and 15 consecutive months. In the record of Honolulu pressure there was one case each of 12, 13, and 20 consecutive months in which pressure was above or below the normal. Such remarkable cases of persistence have not been of such frequent occurrence in Hawaiian rainfall, but beginning with the month of January, 1919, there were 14 consecutive months in which the precipitation was below normal, using Cox's 10-station average.

Evidently, at certain times there is some influence, or group of influences, working, which in itself or themselves tend to persist over a period of several months.

Because of the importance of rainfall in the Hawaiian Islands from a practical standpoint I have made a more exact analysis of the data by finding the coefficient of correlation between each month of the year and the following month. The result is shown in Table 3.

TABLE 3.—*Correlation between Hawaiian rainfall of each month and the following month*

Month beginning	Correlation coefficient r	Probable error e	r/e
January	+0.142	±0.096	1.48
February	+0.126	±0.096	1.31
March	+0.142	±0.096	1.48
April	+0.225	±0.093	2.42
May	+0.394	±0.082	4.80
June	+0.471	±0.076	6.20
July	+0.375	±0.084	4.46
August	+0.394	±0.082	4.80
September	+0.002	±0.099	0.02
October	−0.127	±0.096	1.32
November	+0.321	±0.088	3.65
December	+0.133	±0.096	1.41

It will be observed that the coefficients are much higher during the summer than during other seasons of the year, and the relation thus brought out has some forecast value when applied to summer rainfall for the Hawaiian Islands as a whole. The difference between persistence in the summer and other seasons of the year is present in other meteorological data, and seems to be out of proportion to seasonal differences in variability.

Figure 1 shows the unsmoothed annual values of four meteorological elements, vis, Honolulu temperature, pressure, wind velocity, and Cox's 10-station average of Hawaiian rainfall. Some interesting relations are brought out in this chart. The most important of these is the synchronism between the wind velocity at Honolulu and Hawaiian rainfall, which is not at all surprising in

view of the fact that most of the rainfall in Hawaii is brought about by the forced ascent of the trade winds over the land masses. Another fact, the reason for which is not so evident, is the seesaw relation between pressure and wind movement, and pressure and rainfall. It may be, and probably is, explained by the general principle that high pressure is associated with quiet, clear weather, and low pressure with cloudy, windy weather. Annual temperatures apparently take a course nearly independent of the other elements.
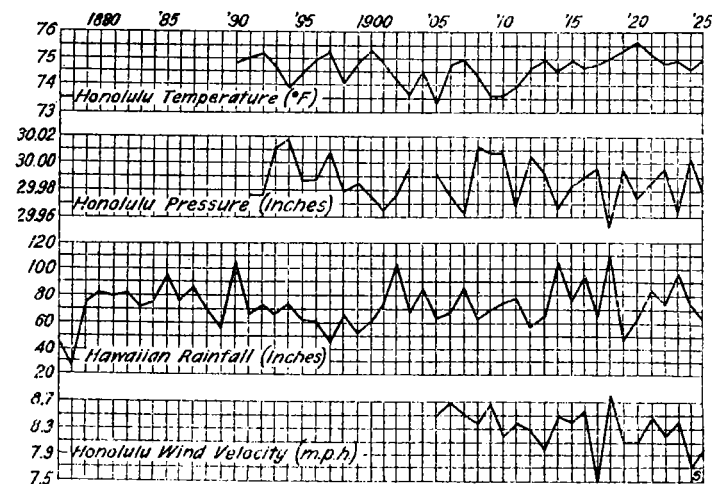
Fig. 1.—Unsmoothed annual values of temperature, pressure, wind velocity, and rainfall (Cox's 10-station average)

CONCLUSIONS

It has been the purpose of this study to show that variations of the weather in the Hawaiian Islands show a systematic tendency, and comparisons were made with the weather elsewhere to show that this tendency was greater than at places in higher latitudes. This, however, could be inferred from what is already known on the subject. Other facts which are new so far as the writer is aware are as follows:

(1) In the Hawaiian Islands, temperatures show a remarkable tendency to persist.

(2) As regards other meteorological elements such as rainfall, atmospheric pressure, and wind velocity, the persistence is less but still clearly apparent in Hawaii.

A knowledge of the fact that wet and dry weather tend to persist considerably in the summer time might be of some value in long-range forecasting. From May to August wet (wetter than normal) months are followed by wet months, and dry (drier than normal) months are followed by dry months in 73 per cent of the cases for the Hawaiian Islands as a whole. For individual sections this would be somewhat less, depending on the locality.

Periodicities probably have little to do with long periods of abnormal weather, and the cause must be sought for elsewhere. The fact that a persistent tendency is shown in the records of weather in the Hawaiian Islands is sufficient to lend encouragement to those who wish to make further studies on longe-range weather forecasting.

LITERATURE CITED

(1) HENRY, A. J.
      1921. TEMPERATURE VARIATIONS IN THE UNITED STATES
            AND ELSEWHERE. Mo. Wea. Rev. 49 : 63–64.
(2) BRAAK, DR. C.
      1919. ATMOSPHERIC VARIATIONS OF SHORT AND LONG
            DURATION IN THE MALAY ARCHIPELAGO AND
            NEIGHBORING REGIONS, AND THE POSSIBILITY TO
            FORECAST THEM. Koninklijk Magnetish en
            Meteorologisch Observatorium te Batavia, Ver-
            handelingen No. 5, Part II.
(3) CLOUGH, H. W.
      1921. A STATISTICAL COMPARISON OF METEOROLOGICAL
            DATA WITH DATA OF RANDOM OCCURRENCE.
            Mo. Wea. Rev. 49 : 124–132.
(4) COX, JOEL B.
      1924. PERIODIC FLUCTUATIONS OF RAINFALL IN HAWAII.
            Transactions, Amer. Society of Civil Engineers.
            Vol. LXXXVII, p. 461.

FORECASTING PRECIPITATION FROM LOCAL DATA [1]

551.578.1 : 551.509

C. L. RAY

The writer has made a statistical arrangement of the probability of rain following different pressure heights, wind directions, pressure changes, and the several combinations of these factors. The results as presented in the accompanying charts and tables do not show a sufficiently high average of probability to serve their intended purpose as an aid in forecasting. The data are presented, however, in order to show what can be done by this method, and to illustrate the relative importance of the several elements, as they relate to forecasting at this station. Owing to the unsatisfactory results from the forecasting angle, averaging not more than 59 per cent, the discussion will be limited to a brief resumé of the more prominent characteristics revealed by the analysis. There was available a total of approximately 5,450 observations, taken daily at 7 a. m., central standard time, throughout the year, and covering a period of 15 years, 1910 to 1925, inclusive. From these data was calculated the percentage of times precipitation occurred within 24 hours, eliminating from consideration the 12 hours immediately following the observation. This gives the results a comparative value in relation to the results from the synoptic charts. Only the annual probabilities have been given in some instances as it was found that the differences were very slight between the values for the several seasons.

TABLE 1.—*Probability of rain with different pressures and different pressure changes, based on 7 a. m. pressure and 12-hour change and rainfall in 24 hours, from 7 p. m., 5,449 observations*

	Spring	Summer	Autumn	Winter	Annual
Pressure (inches):					
29.74, less	69	52	76	82	73
29.75–84	60	44	59	73	59
29.85–94	62	49	58	78	61
29.95–04	60	48	55	70	58
30.05–14	54	49	53	71	56
30.15–24	46	36	45	71	50
30.25 over	42	34	40	61	48
Total	55	46	52	70	56
12-hour pressure change:					
−0.25 inch or more	78		76	77	77
−0.24 inch to −0.15	71	55	65	81	72
−0.14 inch to −0.05	62	56	56	73	63
−0.04 inch to +0.05	60	51	56	72	58
+0.06 inch to +0.15	45	42	45	64	47
+0.16 inch to +0.25	42	34	37	67	46
+0.26 inch and over	51		41	62	53
Total	56	46	52	70	56